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Creators: Watts, Arthur S.

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Clay and Its Engineering Possibilities

By PROF. ARTHUR S. WATTS
Prof. in Ceramic Engineering

CLAY—ITS ORIGIN

To most people clay is "just clay." A material furnished by nature from which we build houses, pave streets, and make all sorts of pottery and dishes. We do not stop to think of its origin or of the wonderful process by which it has come to be in the form in which we find it. Clay is the product of decomposition of feldspar, a silicate of alumina and alkalies, which occurs in nature chiefly in the form of granite. The rain and freezing, and perhaps other forces, have broken down the granite and the water has washed away the alkalies and forced the mass to change its chemical composition. The Feldspar was originally $RO\text{-}Al_2O_3\text{-}6SiO_2$. The water has leached away the alkalies, RO, and the alumina has recombined with two molecules of SiO_2 leaving 4 molecules of silica free. But the water has done more. Two molecules of water have combined with this aluminium silicate forming $Al_2O_3\text{-}2SiO_2\text{-}2H_2O$, known as kaolin. Without the water the mass would not be plastic, i. e. capable of being formed or molded and retaining the form. So much for the origin of "clay" or "kaolin," as the pure form is called by the chemist.

MANUFACTURING PROCESSES

In the process of manufacture, a clay undergoes certain chemical and physical changes. The raw clay may be looked upon as consisting of minute particles each enveloped in a film of water. When the thickness of the film is just sufficient to allow the particles to move freely upon one another under pressure, the mass has its maximum plasticity. An excess of water forces the particles apart and causes the mass to flow and distort without pressure. Insufficient water to form a complete envelope for each particle does not permit the particles to move on one another without rupture and the mass ruptures when pressure is applied, or a strain is created which develops into a crack during the drying or burning process.

Three distinct methods of manufacture are employed in forming clay wares; viz:

(1) Dry pressing, in which the amount of water present is only sufficient to furnish a bond when the clay is subjected to excessive pressure. The clay is prepared as a damp powder and pressed into shape in heavy metal forms or dies.

(2) Plaster molding, in which the amount of water present is sufficient to develop maximum

plasticity, and in this state the clay is modeled or spun into the desired form. For the cruder wares clay in this state is pressed through a die into bars or cylinders and these are cut into the desired length and perhaps repressed to impart the exact form desired.

(3) Casting, in which the amount of water present is sufficient to float the clay particles, and in this state the clay is poured into a mould made of plaster of Paris and having the form of the outside of the product desired. The liquid clay or slip forms a coating upon the plaster mould, the water being absorbed by the plaster of Paris. When the desired thickness of coating is obtained, the remainder of the liquid clay is poured off and the coating soon shrinks loose from the plaster form.

Little progress has been made in the first two methods of manufacture in the past century. The attention of investigators has however been centered for the past five years upon the last named method, i. e. Casting.

The engineer has learned that the plasticity of clay depends upon the physical-chemical state of the clay particles. This state or form we call colloidal and the particles are known as colloids. There are two chief forms of colloids, "sols" and "gels." When in the sol state, the clay particles have contracted to their minimum size and have expelled nearly all the water not chemically combined. These sols act like grains of sand. When in the gel state, the clay particles have expanded to their maximum size and absorbed all the water that they can hold. The control of the colloidal state of clay even after it was known to exist, puzzled technical men for several years. This was due to the fact that scarcely any two clays respond to the same treatment, as regards control of its colloidal content.

Now how does this knowledge apply to the casting of clay ware? First, the amount of water required to bring the clay into the liquid state is vital because the mould will only absorb a certain proportion of its weight of water and this regulates the thickness of the clay coating that can be formed. The clay, if in the sol form, is more compact and does not require so much water to allow its particles to move freely upon one another. Hence a thick wall can be collected in a short time from such clay, and larger pieces of ware can be formed by this process than when the ordinary or gel form of clay was employed. Furthermore the clay in the sol form does not shrink so much as when in the gel form and drying strains are greatly reduced.

By this process the production of many intricate forms of ware are possible which, if made by the laborious process of pressing by hand, would not be commercially practical.

With the ware made, we are next confronted with the drying problem. This is a serious one although little is known of it outside the walls of the factory. The water employed in forming the ware must be removed before it can be subjected to the burning process. It would appear to be only a matter of applying a moderate heat to the ware and evaporating the water as fast as it came to the surface. To draw the water from the inside to the surface of a piece of ware, the surface must be drier than the interior. If this is the case, a greater shrinkage will have occurred and surface cracks will develop in many cases. To prevent this condition the engineer has developed two general methods of drying, (1) low temperature, low humidity, evaporation which cannot carry off the moisture very fast and is controlled by the circulation of the moisture laden air, and (2) high temperature—high humidity, evaporation which likewise cannot carry off the moisture very fast since the atmosphere is saturated when it reaches the ware, and is generally allowed to circulate only very slowly.

The cold air system is most easily controlled but also is the slowest, and requires enormous ventilating equipment. The more modern high temperature—high humidity system is unique in many ways, and has revolutionized drying of many forms of clay wares. The ware as moulded or cast is cold or nearly so. It is placed in enclosed driers and into these a mixture of air and steam is gradually added until the air which is maintained at about 90% saturated has reached a temperature above 212°F. The ware has necessarily absorbed the heat but cannot give up any of the water because the hot air is practically saturated and the moisture absorbed would be immediately recondensed. After the ware has reached the temperature of the air surrounding it, the amount of steam is very slowly decreased and the exterior and interior of the ware remaining at constant temperature the drying strain is reduced to the minimum.

The burning process is divided into two parts,—the destructive changes and the constructive changes. The destructive changes consist of, (a) dehydration, by which the clay loses its combined water, (b) distillation, which includes the liberation of all gaseous material, and (c) oxidation of all combustible bodies. The constructive changes begin when the clay begins to vitrify i. e. when the first of the particles fuse and begin to take others into solution. The process continues with increase of heat until the mass fuses and loses its shape. The mineral constituents of the clay control the temperature at which vitrification begins and the temperature difference between vitrification and fusion.

Application of Clay to Engineering Work

Do you realize that without clay very few of your great engineering processes would be possible? The use of clay for paving and building brick and drain tile, terra cotta and pottery is only a small per cent of its application. We all recognize that concrete as a structural material is enormously useful but when exposed to intense heat is rapidly deteriorated. With clay products no change occurs unless the clay is enclosed and the temperature is beyond that which can be attained by any ordinary conflagration. Burned clay as brick or terra-cotta is vastly superior to concrete as a fire-proofing material when used with steel skeleton. But without clay we could not have steel or iron. The manufacture of iron requires clay as lining for the blast furnaces while steel requires it as lining for the converters. Only the purest forms of clay are adaptable to this branch of engineering. The iron and steel industries are among the largest consumers of fire clays, and fire brick. The blast furnace and steel convertor engineer finds a much greater problem in securing a suitable clay to line his furnace or convertor than in finding iron ore to melt in the furnace. These linings are rapidly dissolved by the slag or gangue of the ore and the cost of relining is one of the biggest expenses of the plants. The glass which you think of as entirely separate from clay is especially dependent upon clay for its manufacture. Sand is plentiful and soda-ash and lime can be manufactured without any difficulty. The big problem of the glass manufacturer today is the securing of suitable clay for lining the tanks or containers in which he fuses the silica sand, soda, and lime. We have had serious difficulty in many glass plants because the clay for the glass tanks had formerly been secured in Europe, and when the present war shut off the shipment of clays, the workmen were some time in becoming accustomed to working the American clays which they were forced to use for the linings. Many plants have found to their delight that they have clays near at hand and much cheaper that are as good as, or better than the European clays they had been using.

The cement industry is also dependent upon clay. A considerable proportion of the compound which is clinkered together to produce Portland cement is clay, and without it we could not produce the cement.

The great developments of our electrical industries are dependent upon clay. Glass which is the only other material adaptable for high tension insulation has many drawbacks which the electrical engineer feels makes it unsuitable for use and today practically all insulation for high tension work is made of clay fused together with additions of feldspar and quartz.

So we see that clay is used for many purposes of which we have never stopped to think and is used or demanded in almost every kind of engineering.

What Our Government Is Doing

What is our government doing to solve the problems that are confronting us as a nation owing to the abnormal conditions arising as a result of the war in Europe? When the war broke out, a lot of our people said that many of our clay industries must suspend operation for the period of the war because they were dependent upon foreign clays. But our government engineers have been working in order to be ready for the day when these foreign supplies should be cut off. Of course we did not anticipate a war—but we did anticipate the exhaustion of the foreign supply or at least such a reduction in the available supply as to arouse the fears of our European competitors and cause them to forbid exportation of crude material. So long as we could use from their store house of material we sat still and did not open our mouths regarding our plans, but when the supply showed signs of being cut off we were forced to show our hands. We have a substitute for the glass maker's famous Klingendorf clay in a washed fire clay of Missouri. We have a substitute for the famous potter's ball clay of Levonshire and Dorsetshire. In fact we have many times the available English supply in the western parts of Kentucky and Tennessee, and the color is far superior to the English material. And for the English china clays upon which we have depended for all our white wares we had the greatest surprise of all. Even our most trusted manufacturer friends did not know the whole truth. We have the pure kaolins of North Carolina and Virginia which are superior to any other kaolins in the world as regards color. Unfortunately what they gain in quality however they lack in quantity and the supply is limited. We have also the Florida kaolins which closely resemble the fine kaolins of Germany and Austria. And last and best we have developed a process whereby the kaolins of Georgia, which have been considered of secondary quality, can be refined to a purity of color and texture equal or superior to the best imported material.

Our government has not been content with laboratory tests on this work. A plant was erected in Georgia and tons of this clay were refined and now we are making this clay into dishes and tiles in some of our largest factories to show that it really will do the work of the imported material. The only complaint that we are receiving is that the color and quality is so superior to the ware made from imported material that the manufacturer can not mix the ware with the old stock on hand.